GSFC 429-00-07-02
ATTACHMENT C

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) PREPARATORY PROJECT (NPP)

SATELLITE MISSION ASSURANCE REQUIREMENTS (MAR)

November 2, 2001

CHECK THE NPP WEBSITE AT http://jointmission.gsfc.nasa.gov TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

INTEGRATED PROGRAM OFFICE
SILVER SPRING, MARYLAND

NPP Satellite
Mission Assurance Requirements (MAR)

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Mission Assurance Requirements (MAR)

for the NPP Satellite

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1.0 INTRODUCTION

This document defines supplemental Safety and Mission Assurance requirements for the NPP satellite delivery order (implementation phase) under the RSDO Rapid II contract. Additional mission assurance requirements are defined in the Rapid II Contract and the NPP Statement of Work. References to the "supplier" or "contractor" in this document are directed to the NPP satellite contractor.

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2.0 SCOPE

These requirements apply to all work accomplished by the satellite contractor and their subcontractors and suppliers of deliverable flight hardware. Non-flight deliverable hardware that interfaces directly with space flight hardware shall be designed and fabricated using space flight materials and processes for any portion of the assemblies that mate with the flight hardware; or that will reside with the space flight hardware in environmental chambers or other test facilities that simulate a space environment (e.g. connectors, test cables, etc.).

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3.0 APPLICABLE DOCUMENTS

The following documents of the latest version at the time of the issue of the NPP Satellite RFO form a part of the Mission Assurance Requirements unless otherwise specified. In the event of a conflict between the documents listed below and this requirements specification, the contents of this specification shall be considered the superseding requirements. In the event of a conflict between this Mission Assurance Requirements document and the Satellite Statement of Work (SOW), the SOW shall take precedence. In the event of any other unresolved conflict, the contracting officer shall be notified, and the order of precedence will be as directed by the contracting officer.

a. Requirements for Soldered Electrical Connections, NASA-STD-8739.3;

b. Requirements for Cabling and Crimping, NASA-STD-8739.4;

c. Requirements for Conformal Coating and Staking of Printed Wiring Boards, NASA-STD-8739.1;

d. Requirements for Surface Mount, NASA-STD-8739.2;

e. Requirements for Electrostatic Discharge Control, NASA-STD-8739.7;

f. Generic Standard on Printed Board Design, IPC-2221;

g. Sectional Design Standard for Rigid Organic Printed Boards, IPC-2222;

h. Qualification/Performance Specification for Rigid Printed Wiring Boards, IPC-6011 & 6012;

i. Process Specification for Rigid Printed Wiring Boards for Space Applications and Other High Reliability Uses, GSFC Supplement S-312-P003;

j. General Environmental Verification Specification for Space Transportation System (STS) and ELV Payloads, Subsystems and Components, GEVS-SE - Rev A, June 1996;

k. NPP Satellite EMI requirements, GSFC 429-01-07-07;

l. GSFC 311-INST-001, Instructions for EEE Parts Selection, Screening and Qualification;

m. NASA Preferred Parts List, PPL-21;

n. Product Cleanliness Levels and Contaminations Control Program, MIL-STD-1246C;

o. Moving Mechanical Assemblies for Space Launch Vehicles, MIL-A-83577B;

p. Destructive Physical Analysis, GSFC S-311-M-70;

q. Fastener Integrity Requirements, GSFC S-313-100 (also numbered GSFC 541-PG-8072.1.2);

r. Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments, MSFC-STD-3029;

s. Eastern and Western Range Safety Requirements, EWR 127-1.

These documents are available at: http://workmanship.nasa.gov; http://nepp.nasa.gov/npsl http://arioch.gsfc.nasa.gov/302/verifhp.htm, and http://standards.nasa.gov/, and http://www.pafb.af.mil/45sw/rangesafety/ewr97.htm.

4.0 REQUIREMENTS

The following sections provide detailed requirements. The delivery schedule for any associated deliverable items is detailed in Attachment D of the NPP Satellite RFO.

4.1 RESERVED

4.2 RELIABILITY ASSESSMENTS

Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL) - A Failure Modes and Effects Analysis (FMEA) shall be performed early in the design phase to identify system design problems. As additional design information becomes available the FMEA shall be refined. Failure modes shall be assessed at the component interface level. Results of the FMEA shall be used to evaluate the design relative to requirements. The Critical Items List shall include item identification, cross-reference to FMEA line items, and retention rationale. Appropriate retention rationale may include design failures, historical performance, acceptance testing, manufacturing product assurance, elimination of undesirable failure modes, and failure detection methods.

Fault Tree Analysis (FTA) - The developer shall perform fault tree analyses (FTA) that address both mission failures and degraded modes of operation in accordance with the SOW. Beginning with each undesired state (mission failure or degraded mission), the fault tree should be expanded to include all credible combinations of events/faults and environments that could lead to that undesired state. Component hardware/software failures, external hardware/software failures, and human factors shall be considered in the analysis. The developer shall make the FTA available to the NPP Project upon request.

Probabilistic Risk Assessment (PRA) - The developer shall use Probabilistic Risk Assessment (PRA) as part of the program's risk management and reliability programs. The developer shall include specific results in their CDR and post-CDR reviews.

The PRA shall be performed in accordance with the CDRL. The PRA shall provide a comprehensive, systematic and integrated approach to identifying undesirable events, the scenarios leading to those events beginning with the initiating event or events, the frequency or likelihood of those events and the event consequences. The assessment shall be used to assist in identifying pivotal events that may protect against, aggravate or mitigate the resulting consequences.

The PRA shall be comprehensive and balanced, and shall consider all relevant critical factors, such as system and personnel safety, adverse impacts on the environment, high value equipment and property, security, etc. The PRA shall reflect and incorporate the results of project risk analyses, including the identification of hazards, risks and recommended controls to manage risk.

The PRA shall include:

a. A definition of the objective and scope of the PRA, and development of end-states-of-interest to the decision-maker,

b. Definition of the mission phases and success criteria,

c. Initiating event categories,

d. Top level scenarios,

e. Initiating and pivotal event models (e.g., fault trees and phenomenological event models),

f. Data development for probability calculations,

g. An integrated model and quantification to obtain risk estimates,

h. An assessment of uncertainties,

i. Summary of results and conclusions, including a ranking of the lead contributors to risk.

4.3 NONCONFORMANCE REPORTS

The NPP Satellite contractor shall maintain a process for promptly documenting and reporting nonconformances to the Government for information and the contractor's internal Anomaly Review Board (ARB) for disposition and corrective action. The contractor shall ensure that a closed-loop reporting system is used to ensure corrective action is implemented to preclude recurrence and to provide verification of the adequacy of implemented corrective action by inspection and test as appropriate.

The satellite contractor shall report nonconformances relative to the spacecraft bus to the Government beginning with the first power application at the start of end item acceptance testing of the major spacecraft bus component or subsystem or upon first operation of a mechanical item (as applicable to the hardware level for which the NPP spacecraft contractor is responsible). Nonconformance reporting shall continue through formal acceptance by the GSFC Project including post-launch operations, commensurate with the NPP spacecraft delivery order. The spacecraft contractor shall document all anomalies occurring at the satellite level including anomalies relating to Government Furnished Equipment (GFE). The spacecraft contractor shall conduct failure investigation for anomalies relative to the spacecraft bus and interface and shall support the investigation of anomalies relative to GFE.

The GSFC/NPP Systems Assurance Manager (SAM) shall serve as an adjunct member of the contractor's ARB and shall receive two hours notice of ARB meetings. Nonconformance reports shall be faxed to the GSFC NPP SAM within 24 hours of anomaly occurrence. Updated information shall be submitted to the SAM by fax prior to each ARB meeting. The NPP SAM shall be notified within 5 working days of nonconformances affecting similar busses.

The contractor shall document failure reports in accordance with company standards. However, these failure reports shall include risk rating of the problem in order to identify significant problems/failures. Contractor format, generation, review, disposition and/or approval of failure reports will be described in applicable procedure(s) included or referenced in the contractor’s System Assurance Plan.

4.4 PRINTED WIRING BOARD (PWB) COUPONS

The NPP satellite contractor shall provide a test coupon for each PWB, or multilayer PWB panel used in flight hardware to GSFC or GSFC-approved laboratory for test, analysis and review. The NPP satellite contractor shall provide test reports for coupons to the GSFC/NPP SAM unless the analysis is performed by GSFC.

PWBs shall be manufactured in accordance with the Class 3 requirements in the IPC PWB manufacturing standards referenced in Section 4.9 and Process Specification for Rigid Printed Wiring Boards for Space Applications and Other High Reliability Uses, GSFC S-312-P-003. The coupons shall only be removed from the flight PWB panel after the panel has been through all manufacturing processes. The coupon shall be "as produced" by the vendor; that is, it shall not have seen any processes not experienced by the PWB panel (including metallographic preparation techniques or thermal excursions). The coupon shall be clearly identified with the part number, serial number, vendor identification and date code or production lot number.

4.5 GIDEP PARTICIPATION

The NPP satellite contractor shall participate in the Government/Industry Data Exchange Program (GIDEP). The contractor shall transmit additional copies of documentation sent to GIDEP relevant to the NPP spacecraft bus to the GSFC NPP SAM and to the:

Alert Coordinator
Code 562
NASA Goddard Space Flight Center
Greenbelt, MD 20771

4.6 GIDEP ALERT RESPONSES

The NPP satellite contractor shall be responsible for review and disposition of Government Industry Data Exchange Program (GIDEP) Alerts for applicability to the parts proposed for use. Review and disposition includes determining applicability, impact and proposed corrective action for each GIDEP Alert. In addition, any NASA Alerts and Advisories provided to the NPP satellite contractor by GSFC shall be reviewed and dispositioned. Alert applicability, impact, and proposed corrective actions shall be documented and be made available for GSFC review. A monthly status report shall be submitted to the NPP Project indicating the Alerts reviewed for applicability, the status of the associated hardware or documentation review, impact to the program and proposed corrective action. This report may be part of the project status report or a copy of the contractor's internal report.

4.7 AS-DESIGNED/AS-BUILT PARTS, MATERIALS, PROCESSES AND LUBRICATIONS LISTS AND EEE PART AND MATERIALS REQUIREMENTS

4.7.1 Parts, Materials, Processes and Lubrications Lists

The As-Designed Parts, Materials, Processes and Lubrications List shall include the planned configuration of delivered articles. The As-Built Parts, Materials, Processes and

Lubrications List shall detail the actual configuration of the delivered articles. This information will be used by NASA/GSFC to ensure that parts and materials used in the spacecraft do not compromise the operation of the sensors and instruments on the satellite.

These lists shall detail, as a minimum, the configuration of the delivered items by delineating the following details for each major subassembly contained within the article(s) to be delivered:

(a) Hardware subsystems

1. Nomenclature
2. Specification/assembly identification number
3. Serial number
4. As-designed revision number

(b) Software items

1. Software module title
2. Code identification or serial number
3. Software inventory numbering system
4. Module revision number

4.7.1.1 Inorganics and Composites List

The NPP satellite contractor shall provide information for inorganics and composites usage as indicated in form GSFC 18-59A 3/78 (Figure 1).

4.7.1.2 Polymeric Materials and Composites List

The NPP satellite contractor shall provide information for polymeric materials and composites usage as indicated in form GSFC 18-59B 3/78 (Figure 2).

4.7.1.3 Lubrication Usage List

The NPP satellite contractor shall provide information for lubricant usage as indicated in form GSFC 18-59C 3/78 (Figure 3).

4.7.1.4 Material Process Utilization List

The NPP satellite contractor shall provide information for material process usage as indicated in form GSFC 18-59D 3/78 (Figure 4).

INORGANIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT______________________ SYSTEM/EXPERIMENT______________________ GSFC T/O ____________

DEVELOPER/CONTRACTOR ______________________ ADDRESS______________________

PREPARED BY______________________ PHONE______________________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ______________________ PHONE____________ DATE RECEIVED ____________ DATE EVALUATED____________

ITEM NO.	MATERIAL IDENTIFICATION (2)	CONDITION (3)	APPLICATION (4) OR OTHER SPEC. NO.	EXPECTED ENVIRONMENT (5)	S.C.C. TABLE NO.	MUA NO.	NDE METHOD

NOTES:

1. List all inorganic materials (metals, ceramics, glasses, liquids and metal/ceramic composites) except bearing and lubrication materials which should be listed on Form 18-59C.
2. Give materials name, identifying number manufacturer.
   Example: a. Aluminum 6061-T6
   b. Electroless nickel plate, Enplate Ni 410, Enthone, Inc
   c. Fused silica, Corning 7940, Corning Class Works
3. Give details of the finished condition of the material, heat treat designation (hardness or strength), surface finish and coating, cold worked state, welding, brazing, etc.
   Example: a. Heat treated to Rockwell C 60 hardness, gold electroplated, brazed.
   b. Surface coated with vapor deposited aluminum and magnesium fluoride
   c. Cold worked to full hare condition, TIG welded and electroless nickel plated.
4. Give details of where on the spacecraft the material will be used (component) and its function.
   Example: Electronics box structure in attitude control system, not hermetically sealed.
5. Give the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
   Example: T/V: -20C/+60C, 2 weeks, 10E-5 torr, Ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 miles altitude, UV, electron, proton, Atomic Oxygen

GSFC 18-59A 3/78

Figure 1 - Inorganic Materials And Composites Usage List

POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT____________________ SYSTEM/EXPERIMENT____________________ GSFC T/O ____________

DEVELOPER/CONTRACTOR ____________________ ADDRESS____________________

PREPARED BY____________________ PHONE____________________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ____________________ PHONE____________ DATE RECEIVED ____________ DATE EVALUATED ____________

Area, cm^2	Vol., cc	Wt., gm
1 0-1	A 0-1	a 0-1
2 2-100	B 2-50	b 2-50
3 101-1000	C 51-500	c 51-500
4 >1000	D >500	d >500

ITEM NO.	MATERIAL IDENTIFICATION (2)	MIX FORMULA (3)	CURE (4)	AMOUNT CODE	EXPECTED ENVIRONMENT (5)	REASON FOR SELECTION (6)	OUTGASSING VALUES	
							TML	CVCM

NOTES

1. List all polymeric materials and composites applications utilized in the system except lubricants which should be listed on polymeric and composite materials usage list.

2. Give the name of the material, identifying number and manufacturer. Example: Epoxy, Epon 828, E. V. Roberts and Associates

3. Provide proportions and name of resin, hardener (catalyst), filler, etc. Example: 828/V140/Silflake 135 as 5/5/38 by weight

4. Provide cure cycle details. Example: 8 hrs. at room temperature + 2 hrs. at 150C

5. Provide the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. List all materials with the same environment in a group. Example: T/V : -20C/+60C, 2 weeks, 10E-5 torr, ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 mile altitude, UV, electron, proton, atomic oxygen

6. Provide any special reason why the materials was selected. If for a particular property, please give the property.
   Example: Cost, availability, room temperature curing or low thermal expansion.

GSFC 18-59B 3/78

Figure 2 - Polymeric Materials And Composites Usage List

LUBRICATION USAGE LIST

SPACECRAFT______________________ SYSTEM/EXPERIMENT______________________ GSFC T/O ____________

DEVELOPED/CONTRACTOR ______________________ ADDRESS______________________

PREPARED BY______________________ PHONE______________________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ______________________ PHONE ____________ DATE RECEIVED ____________ DATE EVALUATED____________

ITEM NO.	COMPONENT TYPE, SIZE MATERIAL[1]	COMPONENT MANUFACTURER & MFR. IDENTIFICATION	PROPOSED LUBRICATION SYSTEM & AMT. OF LUBRICANT	TYPE & NO. OF WEAR CYCLES[2]	SPEED, TEMP., ATM. OF OPERATION[3]	TYPE OF LOADS & AMT.	OTHER DETAILS[5]

NOTES

(1) BB = ball bearing, SB = sleeve bearing, G = gear, SS = sliding surfaces, SEC = sliding electrical contacts. Give generic identification of materials used for the component, e.g., 440C steel, PTFE.

(2) CUR = continuous unidirectional rotation, CO = continuous oscillation, IR = intermittent rotation, IO = intermittent oscillation, SO = small oscillation, (<30°), LO = large oscillation (>30°), CS = continuous sliding, IS = intermittent sliding.
No. of wear cycles: A($1-10^2$), B(10^2-10^4), C(10^4-10^6), D($>10^6$)

(3) Speed: RPM = revs./min., OPM = oscillations/min., VS = variable speed
CPM = cm/min. (sliding applications)
Temp. of operation, max. & min., °C
Atmosphere: vacuum, air, gas, sealed or unsealed & pressure

(4) Type of loads: A = axial, R = radial, T = tangential (gear load). Give amount of load.

(5) If BB, give type and material of ball cage and number of shields and specified ball groove and ball finishes. If G, give surface treatment and hardness. If SB, give dia. of bore and width. If torque available is limited, give approx. value.

GSFC 18-59C 3/78

Figure 3 - Lubrication Usage List

MATERIALS PROCESS UTILIZATION LIST

SPACECRAFT__________ SYSTEM/EXPERIMENT__________ GSFC T/O __________

DEVELOPER/CONTRACTOR __________ ADDRESS__________

PREPARED BY__________ PHONE__________ DATE PREPARED __________

GSFC MATERIALS EVALUATOR __________ PHONE__________ DATE RECEIVED __________ DATE EVALUATED __________

ITEM NO.	PROCESS TYPE[(1)]	CONTRACTOR SPEC. NO.[(2)]	MIL., ASTM., FED. OR OTHER SPEC. NO.	DESCRIPTION OF MAT'L PROCESSED[(3)]	SPACECRAFT/EXP. APPLICATION[(4)]

NOTES

(1) Give generic name of process, e.g., anodizing (sulfuric acid).

(2) If process if proprietary, please state so.

(3) Identify the type and condition of the material subjected to the process. E.g., 6061-T6

(4) Identify the component or structure of which the materials are being processed. E.g., Antenna dish

GSFC 18-59D 3/78

Figure 4 - Materials Process Utilization List

4.7.1.5 Parts List

Each parts list shall be a composite of the parts selections for each circuit design in the component, including EEE parts. As a minimum, unless otherwise agreed to by the Parts Control Board, each list shall contain the following information:

(a) Part number
(b) Description
(c) Next assembly
(d) Trace ID
(e) Quantity issued/used
(f) Serial Number
(g) Order Type
(h) P.O. Number
(i) Name or Commercial and Government Entity (CAGE) Code of the part manufacturer
(j) Manufacturing lot date code
(k) Vendor ID
(l) System used
(m) Part specification control drawing number
(n) Common designator or generic number
(o) Drawing number of component to which the list pertains.

This data is to be supplied electronically in a spreadsheet format (i.e., Access, Excel, etc.). The PCB may approve specific deviations to items (a) through (o) if the data is available from the contractor in an alternative format or location.

4.7.2 EEE Part Requirements

4.7.2.1 General

The NPP satellite contractor shall plan and implement an Electrical, Electronic, and Electromechanical (EEE) Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability.

The NPP satellite contractor shall provide a Parts Control Plan (PCP) describing the approach and methodology for implementing the Parts Control Program. The PCP will also define the NPP satellite contractor's criteria for parts selection and approval based on the requirements of this section.

4.7.2.2 Electrical, Electronic, and Electromechanical (EEE) Parts

All part commodities identified in the NASA Parts Selection List are considered EEE parts and will be subjected to the requirements set forth in this section. Custom or advanced technology devices such as custom hybrid microcircuits, detectors, Application Specific Integrated Circuits (ASIC) and Multi-Chip Modules (MCM) shall also be subject to parts control appropriate for the individual technology.

4.7.2.3 Parts Control Board

The NPP satellite contractor shall establish a Parts Control Board (PCB) or a similar documented system to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the contract. The PCB shall be responsible for the review and approval of all parts for conformance to established criteria, and for developing and maintaining a Parts Identification List (PIL). In addition, the PCB shall be cognizant of all parts activities such as failure investigations, disposition of non-conformances, and problem resolutions. PCB operating procedures shall be referenced as part of the PCP.

4.7.2.4 Parts Control Board Meetings

PCB meetings shall be convened on a regular basis or as needed. GSFC may participate in PCB meetings and shall be notified at least two hours in advance of all upcoming meetings. The NPP satellite contractor will maintain meeting minutes or records to document all decisions made and provide a copy of the minutes to GSFC within five working days of the meeting.

4.7.2.5 Parts Selection and Processing

All parts shall be selected and processed in accordance with Instructions for EEE Parts Selection, Screening and Qualification, GSFC 311-INST-001. All application notes in GSFC 311-INST-001 will apply. All EEE parts shall be procured to Level 2 or better. These requirements will then become the established criteria for parts selection, testing, and approval for the duration of the Project, and will be documented in the PCP. Parts selected from the NASA Parts Selection List, MIL-STD-975, and the GSFC Preferred Parts List (PPL) are considered to have met all criteria of GSFC 311-INST-001 for the appropriate parts quality level, and may be approved by the PCB provided all mission application requirements (performance, de-rating, radiation, etc.) are met.

4.7.2.6 Custom Devices

In addition to applicable requirements of GSFC 311-INST-001, custom microcircuits, hybrid microcircuits, MCM, ASIC, etc. planned for first use by the NPP satellite contractor shall be subjected to a design review. The review may be conducted as part of the PCB activity. The design review will address, at a minimum, de-rating of elements, method used to assure each element reliability, assembly process and materials, and method for assuring adequate thermal matching of materials.

4.7.2.7 De-rating

All EEE parts shall be used in accordance with the de-rating guidelines of the NASA Preferred Parts List, PPL-21. The NPP satellite contractor's de-rating policy may be used in place of the NASA Parts Selection List guidelines with the approval of the PCB. The NPP satellite contractor shall maintain documentation on parts de-rating analysis and shall make it available for GSFC review.

4.7.2.8 Radiation Hardness

All parts shall be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of two separate effects, those of total ionizing dose and single-event effects. The NPP satellite contractor shall document the analysis for each part with respect to both effects. The possibility of displacement damage shall also be considered for parts susceptible to this effect.

4.7.2.9 Plating

Pure tin plating is prohibited as a final finish on EEE parts and associated hardware unless approved by the PCB. Cadmium plating is prohibited on EEE parts and associated hardware unless approved by the PCB. Zinc plating is prohibited on EEE parts and associated hardware unless approved by the PCB.

4.7.2.10 Destructive Physical Analysis

A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices shall be subjected to a Destructive Physical Analysis (DPA) if a DPA was not performed as part of the manufacturer's qualification program. All other parts may require a sample DPA if it is deemed necessary by the PCB as indicated by failure history, GIDEP Alerts, or other reliability concerns. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification Destructive Physical Analysis, S-311-M-70. NPP satellite contractor's procedures for DPA may be used in place of GSFC S-311-M-70 and shall be referenced in the PCP. Variation to the DPA sample size requirements, due to part complexity, availability or cost, shall be determined and approved by the PCB on a case-by-case basis.

4.7.2.11 Parts Age Control

Parts drawn from controlled storage after 5 years from the date of the last full screen shall be subjected to a full 100 percent re-screen and sample DPA. Alternative test plans, including the waiving of the re-screen and/or DPA if appropriate, may be used as determined and approved by the PCB on a case-by case basis. Parts over 10 years from the date of the last full screen or stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall be submitted to the PCB for approval prior to use.

4.7.2.12 Traceability

The NPP satellite contractor shall maintain a product identification and tracking system. Identification and serialization data for EEE parts shall be maintained in the manufacturing and processing records and shall contain lot date code, lot and purchase order numbers, and manufacturer of the part. The NPP satellite contractor shall ensure that markings for small chip devices (usually printed on the parts' packaging) are recorded in the manufacturing and processing records prior to use.

4.7.3 Materials Requirements

4.7.3.1 General

In order to anticipate and minimize materials problems during space hardware development and operation, the developer shall, when selecting materials and lubricants, consider potential problem areas such as radiation effects, thermal cycling, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled surfaces, composite materials, atomic oxygen, useful life, vacuum outgassing, toxicity, flammability and fracture toughness, as well as the properties required by each material usage or application.

4.7.3.2 Fasteners

The developer shall comply with the procurement documentation and test requirements for flight hardware and critical ground support equipment fasteners contained in Goddard Space Flight Center Fastener Integrity Requirements, GSFC S-313-100. Material test reports for fastener lots shall be available upon request.

Fasteners made of plain carbon or low alloy steel shall be protected from corrosion. When plating is specified, it shall be compatible with the space environment. On steels harder than RC 33, plating shall be applied by a process that is not embrittling to the steel.

4.7.3.3 Flammability and Toxicity

Satellite materials shall meet the requirements of Range Safety Requirements, Eastern and Western Range 127-1, for usage of hazardous materials.

4.7.3.4 Vacuum Outgassing

Material vacuum outgassing shall be determined in accordance with American Society for Testing of Materials ASTM E-595. Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment.

4.7.3.5 Shelf-Life-Controlled Materials

Polymeric materials that have a limited shelf-life shall be controlled by a process that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date.

Materials such as O-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints shall be included. The use of materials whose date code has expired requires that the developer demonstrate, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use.

4.7.3.6 Inorganic Materials

The criteria specified in Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments, MSFC- STD-3029, shall be used to determine that metallic materials meet the stress corrosion cracking criteria.

4.7.3.7 Mechanisms

Spacecraft deployable mechanisms shall be compliant with Moving Mechanical Assemblies for Space Launch Vehicles, MIL-A-83577B.

4.8 MATERIAL REVIEW BOARD (MRB)

The contractor shall withhold discrepant products from further processing in a controlled area until disposition. Discrepant products shall be reviewed by NPP satellite contractor quality assurance and engineering personnel and shall be subjected to one of the following dispositions:

a. Return for Rework or Completion of Operations - The product shall be returned using established and approved documents and operations. During rework, the product shall be resubmitted to normal inspection and tests;

b. Scrap in accordance with developer procedures for identifying, controlling and disposing of scrap;

c. Return to Supplier - The contractor shall provide the supplier with nonconformance information and assistance, as necessary, to permit remedial and preventive action;

d. Submit to Material Review Board - When the dispositions, as described above, are not appropriate, the discrepant products shall be submitted to the Material Review Board (MRB) for final disposition.

Initial review dispositions shall be recorded on nonconformance documentation. MRB recommendations for nonconforming material shall be submitted to the NPP SAM in accordance with 4.3 herein.

Other provisions of the MRB follow:

a. Membership. The MRB shall comprise, as a minimum, the following members:

   1) Contractor quality representative, chairman;

   2) Contractor engineering representative;

3) Government quality representative (NPP SAM or designee as an adjunct member).

b. Responsibilities - The MRB shall have the responsibility to:

1) Determine disposition of submitted products;

2) Ensure that remedial and preventive actions, including reinspection and retest requirements, are recorded on MRB documentation prior to disposition;

3) Perform trend analysis of discrepancies;

4) Ensure that MRB records are maintained.

c. Dispositions - In addition to the dispositions listed above, the MRB shall have authority for the following:

1) Repair - The MRB shall approve repairs. Standard Repair Procedures shall be submitted to the GSFC/NPP SAM prior to use. The MRB shall authorize the use of the procedures for each instance of repair. The MRB shall ensure that the hardware reliability and quality are not compromised by excessive repairs;

2) Scrap;

3) Use-as-is.

MRB disposition shall not adversely affect the safety, reliability, durability, performance, interchangeability, weight, or other basic features of the hardware.

4.9 WORKMANSHIP AND PROCESSES

The NPP satellite contractor shall be compliant to the following workmanship standards:

a. Requirements for Soldered Electrical Connections, NASA-STD-8739.3;

b. Requirements for Cabling and Crimping, NASA-STD-8739.4;

c. Requirements for Conformal Coating and Staking of Printed Wiring Boards, NASA-STD-8739.1;

d. Requirements for Surface Mount, NASA-STD-8739.2;

e. Requirements for Electrostatic Discharge Control, NASA-STD-8739.7;

f. Generic Standard on Printed Board Design, IPC-2221;

g. Sectional Design Standard for Rigid Organic Printed Boards, IPC-2222;

h. Qualification/Performance Specification for Rigid Printed Wiring Boards, IPC-6011 & 6012;

i. Process Specification for Rigid Printed Wiring Boards for Space Applications and Other High Reliability Uses, GSFC Supplement S-312-P003.

4.10 CLARIFICATION OF PERFORMANCE VERIFICATION REQUIREMENTS

4.10.1 General Requirements

Per paragraph 4.3.4.3 of the NPP Satellite Statement of Work (SOW), the developer shall plan, manage and execute satellite level interface verification, system testing, and environmental testing in order to ensure that the NPP spacecraft bus and satellite meet the specified mission requirements. The satellite performance verification program begins with functional testing of assemblies, continues through the functional and environmental testing, supported by appropriate analysis, at the component and subsystem levels of assembly. Methods for implementing the requirements of this Section are contained in the expendable launch vehicle (ELV) payload requirements of the General Environmental Verification Specification for Space Transportation System (STS) and ELV Payloads, Subsystems and Components (GEVS-SE). For the purposes of this document, the activities included in the satellite performance verification program include: electrical functional tests, structural and mechanical tests, electromagnetic compatibility tests, vacuum and thermal tests, and pre-launch flight operations tests (see SOW paragraph 4.3.4.3, Test and SOW paragraph 5.3.5.2.2, Pre-Launch Testing).

The contractor shall establish the general environmental test requirements for the NPP mission based on the ELV payload requirements of GEVS-SE and the mission requirements. Test levels shall encompass predictions based on launch vehicle information. Test requirements shall be updated if necessary based on satellite structural analyses and modal survey.

4.10.2 Documentation Requirements

The approach for accomplishing the satellite performance verification program shall be described as part of the Spacecraft and Satellite Integration and Test Plan (see SOW Section 4.3.2.2 and CDRL 7). This shall include a description of the management approach as well as references to applicable plans, specifications, procedures, and reports, which define the technical aspects of the satellite performance verification program.

The Spacecraft and Satellite Integration and Test Plan shall include the definition of specific tests and analyses that collectively demonstrate that the hardware and software/firmware complies with sections 4.10.2 through 4.10.7 of this document.

The Spacecraft and Satellite Integration and Test Plan shall include the overall approach to accomplishing the satellite verification program in addition to the other requirements listed in CDRL 7. For each performance verification test, the plan shall include the level of assembly, configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control, test phases and profiles, necessary functional operations, personnel responsibilities, and requirements for procedures and reports. The plan shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described. For each analysis activity, the plan shall include objectives, a description of the mathematical model, assumptions on which the models will be based, required output, criteria for assessing the acceptability of the results, the interaction with related test activity, if any, and requirements for reports.

The Satellite Performance Verification Plan shall summarize all tests and analyses that will be performed on each component, each subsystem, the spacecraft bus, and the satellite, as a whole. The contractor shall update the test matrix as the contractor/subcontractor tests are actually accomplished throughout the program and present it at pertinent GSFC reviews.

For each functional and environmental test activity conducted at the component, subsystem, spacecraft bus, and satellite level, verification procedures shall be prepared that describe the configuration of the test article and how that particular test activity contained in the Spacecraft and Satellite Integration and Test Plan will be implemented. The procedures shall describe details such as instrumentation monitoring, facility control sequences, test article functions, test parameters, quality control checkpoints, pass/fail criteria, data collection, and reporting requirements. The procedures shall also have attached test predictions and shall address safety and contamination control provisions and measures to protect the hardware (e.g. connector savers). Procedures for calibrations and performance tests shall provide for real-time display of data in easily recognized engineering terms to the maximum extent practicable. Verification Procedures shall be made available to the Government upon request.

4.10.3 Electrical Function Test Requirements

4.10.3.1 Electrical Interface Tests - Before the integration of an assembly, component, or subsystem into the next higher hardware assembly, electrical interface tests shall be performed to verify that all interface signals are within acceptable limits of applicable performance specifications.

Prior to mating with other hardware, electrical harnessing shall be tested to verify proper characteristics; such as, routing of electrical signals, impedance, isolation, and overall workmanship.

4.10.3.2 Performance Tests

4.10.3.2.1 Comprehensive Performance Tests (CPTs). A CPT shall be conducted on each hardware element upon completion of integration of all assemblies. When environmental testing is performed at a given level of assembly, additional CPTs shall be conducted during the hot and cold extremes of the temperature or thermal-vacuum test and at the conclusion of the environmental test sequence, as well as at other times prescribed in the Verification Specification.

The CPT shall be a detailed demonstration that the hardware and software meets their performance requirements within allowable tolerances. The test shall demonstrate operation of all redundant circuitry. It shall also demonstrate satisfactory performance in all operational modes within practical limits of cost, schedule, and environmental simulation capabilities. The initial CPT shall serve as a baseline against which the results of all later CPTs are compared.

At the spacecraft bus and satellite levels, the CPT shall demonstrate that, with the application of known stimuli, the system will produce the expected responses. At lower levels of assembly, the test shall demonstrate that, when provided with appropriate stimuli, internal performance is satisfactory and outputs are within acceptable limits.

4.10.3.2.2 Limited Performance Tests. Limited performance tests shall be conducted before, during, and after environmental tests, as appropriate, in order to demonstrate that functional capability has not been degraded by the environmental tests. Limited performance tests are also used in cases where a CPT is not warranted or not practicable. Specific times at which limited performance tests will be conducted shall be prescribed in the Verification Specification. Limited performance tests shall demonstrate that the performance of selected functions is within acceptable limits.

4.10.3.2.3 Trouble Free Performance. At the conclusion of the performance verification program, the satellite shall have demonstrated minimum reliability acceptability by trouble-free performance for at least the last 100 hours of (combined) testing prior to shipment to the launch site. Trouble-free operation during the thermal vacuum test exposure and during testing of the integrated satellite may be included as part of the demonstration. Hardware or software changes prior to shipment to the launch site shall invalidate previous demonstration.

4.10.4 Structural and Mechanical Requirements

4.10.4.1 General Requirements - The contractor shall demonstrate compliance with structural and mechanical requirements with a series of interdependent test and analysis activities. The baseline requirements are stated in the ELV payload requirements of GEVS-SE. The demonstrations shall verify design and specified factors of safety, ensure interface compatibility among the elements of the satellite and with the launch vehicle, acceptable workmanship, and compliance with associated systems safety requirements.

4.10.4.2 Requirements Summary - Table 4.10-1 specifies the structural and mechanical verification activities. When planning the tests and analyses, the contractor shall consider all expected environments including those of structural loads, vibroacoustics, mechanical shock, and pressure profiles. Mass properties and mechanical functioning shall also be verified.

4.10.4.3 Structural Loads

4.10.4.3.1 Verification for Design Qualification. Verification for the structural loads environment shall be accomplished by a combination of test and analysis. A modal survey shall be performed to verify that the analytic model of the NPP satellite hardware adequately represents its dynamic characteristics. All significant modes up to 50 Hz must be determined both in terms of frequency and mode shape. Cross-orthogonality checks of the test and analytical mode shapes, with respect to the analytical mass matrix, shall be performed with the goal of obtaining at least 0.9 on the diagonal and no greater than 0.1 off diagonal. The test-verified model shall then be used to predict the maximum expected load for each potentially critical loading condition, including handling and transportation, and vibroacoustic effects during lift-off. The maximum loads resulting from the analysis define the limit loads.

4.10.4.3.2 Design Strength Qualification - The preferred method of verifying adequate strength is to apply a set of loads equal to 1.25 times the limit loads, after which the hardware must be capable of meeting its performance criteria (see special requirements for beryllium structure below). As many test conditions shall be applied as necessary to subject the hardware to the worst-case loads. No detrimental permanent deformation shall be allowed to occur as a result of applying the loads, and all applicable alignment requirements must be met following the test.

The strength qualification test must be accompanied by a stress analysis that demonstrates positive margins of safety on ultimate failure at loads equal to 1.4 times the limit load and on yielding at loads equal to 1.25 time the limit load. See special requirements for beryllium structure below.

In addition, the analysis shall show that at stresses equal to the limit load, the maximum allowable loads at the launch vehicle interface points are not exceeded and that no excessive deformations occur that might constitute a hazard to the mission. This analysis shall be performed prior to the start of the strength qualification tests to provide minimal risk of damage to hardware.

a. Selection of Test Method - The qualification load conditions may be applied by acceleration testing, static load testing, or vibration testing (either transient, fixed frequency or swept sinusoidal excitation). Random vibration is generally not acceptable for loads testing.

b. Test Setup - The test item shall be attached to the test equipment by a fixture whose mechanical interface simulates the mounting of the test item into the payload with particular attention paid to duplicating the actual mounting contact area. In mating the subsystem to the fixture, a flight-type mounting (including vibration isolators or kinematic mounts if part of the design) and fasteners shall be used.

   Components that are normally sealed shall be pressurized during the test to their prelaunch pressure. In cases when significant changes in strength, stiffness, or applied load result from variations in internal and external pressure during the launch phase, a special test shall be considered to cover those effects.

   When acceleration testing is performed, the centrifuge shall be large enough so that the applied load at the extreme ends of the test item does not differ by more than 10 percent from that applied to the center of gravity. In addition, when the proper orientation for the applied acceleration vector is computed, ambient gravity effects shall be considered.

c. Performance - Before and after the strength qualification test, the test item shall be examined and functionally tested to verify compliance with all performance criteria. During the tests, performance shall be monitored in accordance with the verification specification and procedures.

If appropriate development tests are performed to verify accuracy of the stress model, stringent quality control procedures are invoked to ensure conformance of the structure (materials, fasteners, welds, processes, etc.) to the design, and the structure has well-defined load paths, then strength qualification may (with payload project concurrence) be accomplished by a stress analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the limit load, and positive margin on ultimate at loads equal to 2.6 times the limit load. Factors of safety lower than 2.0 on yield and 2.6 on ultimate will be considered when they can be shown to be warranted. Justification for the lower factors of safety must be based on the merits of a particular combination of test and analysis and a correlation of the two. In addition, at stresses equal to the limit load, the analysis shall show that the maximum allowable loads at the launch vehicle interface points are not exceeded and that no excessive deformations occur.

Structural elements fabricated from composite materials or beryllium shall not be qualified by analysis alone. All beryllium primary and secondary structural elements shall undergo a strength test to 1.4 times limit load. No detrimental permanent deformation shall be allowed to occur as a result of applying the loads, and applicable alignment requirements must be met following the test.

Table 4.10-1 Structural and Mechanical Verification Requirements

Requirement	Satellite	Modular Subsystem	Component (of Spacecraft Bus)
Structural Loads:			
Modal Survey	A-T	T1	A/T2
Load Tests:			
Design qual	A-T	A; T	A; T1
Structural Rel.	A/T	A/T	A/T
Vibroacoustics:			
Acoustics	T	T1	T1
Random Vibration	-	T1	T
Sine Vibration	T3	T3	T3
Mechanical Shock	T	T	-
Mechanical Function	A; T	T	T
Pressure Profile	A; T1	A; T1	-
Mass Properties	A/T	A; T	A; T4

A-T = Analysis required and must be verified by testing. Test may be performed at satellite, spacecraft bus, or satellite hardware model level of assembly, as appropriate.

A = Analysis required.

A/T = Analysis and/or test.

A/T2 = Analysis required; test only if dictated by analysis.

T = Test required.

T1 = Test must be performed unless analysis and preliminary test results, e.g. frequency
verification prior to modal survey testing, can be used to justify deletion.

T3 = Test performed to simulate any sustained periodic mission environment or to satisfy
other requirement (e.g., loads, shock)

T4 = Test must be performed at payload level of assembly to simulate transient and any sustained periodic vibration mission environment.

4.10.4.4 Vibroacoustics

4.10.4.4.1 Verification for Design Qualification. For the vibroacoustics environments, limit levels are equal to the maximum expected flight environment. Qualification levels are defined as limits plus 3 dB. When random vibration levels are determined, responses to the acoustic inputs plus the effects of vibration transmitted through the structure shall be considered. As a minimum for heritage or previously qualified hardware, component random vibration levels shall be sufficient to demonstrate acceptable workmanship. For qualification of hardware, tests shall be conducted on each of three mutually perpendicular axes for one minute each. When the instrument or component contains delicate optics, detectors, sensors, etc., that could be damaged in certain frequency bands, and if it can be shown that these levels result in unrealistically high loads, the test levels may be reduced in those frequency bands.

4.10.4.5 Sine Vibration

4.10.4.5.1 Verification for Design Qualification. The satellite shall be subjected to swept sine vibration testing from 5 to 50 Hz to qualify the hardware for the low-frequency sine transient or sustained sine environments present in flight, and to provide a workmanship test for all payload hardware that normally does not respond significantly to the acoustic environment, such as wiring harnesses and stowed appendages.

The satellite in its launch configuration shall be attached to a vibration fixture by use of a flight-type launch-vehicle attach fitting and separation system. Sine sweep vibration shall be applied at the base of the launch vehicle adapter in each of three orthogonal axes, one of which is parallel to the thrust axis. The test shall represent the qualification level (flight limit level times 1.25). The test sweep rate shall be 4 octaves per minute to simulate the flight sine transient vibration; lower sweep rates shall be used in the appropriate frequency bands as required to match the duration and rate of change of frequency of any flight sustained, pogo-like vibration. The test shall be performed by sweeping the applied vibration once through the 5 to 50 Hz frequency range in each test axis.

Before and after each test exposure, the test item shall be examined and functionally tested. During the test, performance shall be monitored in accordance with the contractor's verification specification.

4.10.4.6 Mechanical Shock

4.10.4.6.1 Verification for Design Qualification. Both self-induced and externally-induced shocks shall be considered in defining the mechanical shock environment. All satellite subsystems shall be exposed to all self-induced shocks by actuation of the shock-producing devices. Each device must be actuated twice in order to account for the scatter associated with different actuations of the same device. In addition, when the most severe shock is externally induced, a suitable simulation of that shock shall be applied at the subsystem interface. When it is feasible to apply this shock with a controllable shock-generating device, the verification level shall be 1.4 times the maximum expected value at the subsystem interface, and shall be applied once in each of the three axes. If it is not feasible to apply the shock with a controllable shock-generating device (e.g., the subsystem is too large for the device), this test may be conducted at the spacecraft bus or satellite level by actuation of the shock-producing devices in the elements of the satellite, which produce the shocks external to the subsystem to be tested. Satellite separation shock shall also be verified by actuation of the shock-producing devices at spacecraft level. The shock-producing device(s) must be actuated a minimum of two times for this test.

4.10.4.7 Mechanical Function

4.10.4.7.1 Verification for Design Qualification. A kinematic analysis of all satellite mechanical operations is required to:

(a) ensure that each mechanism can perform satisfactorily and has adequate margins under worst-case conditions;

(b) ensure that satisfactory clearances exist for both the stowed and operational configurations as well as during any mechanical operation;

(c) ensure that all mechanical elements are capable of withstanding the worst-case loads that may be encountered.

In addition, verification tests are required to demonstrate that the installation of each mechanical device is correct and that no problems exist that will prevent proper operation of the mechanism during mission life.

Verification tests are required for each mechanical operation at nominal, low, and high energy levels. To establish that mechanical function is proper for normal operations, the nominal test shall be conducted at the most probable conditions predicted during normal flight. A high-energy test and a low-energy test shall also be conducted to prove positive margins of strength and function. The levels of these tests shall demonstrate margins beyond the nominal conditions by considering adverse interaction of potential extremes of parameters such as temperature, friction, spring forces, stiffness of electrical cabling or thermal insulation, and, when applicable, spin rate. Parameters to be varied during these high- and low-energy tests shall include, to the maximum extent practicable, all those that could substantively affect the operation of the mechanism, as determined by the results of analytic predictions or development tests. As a minimum, however, successful operation at temperature extremes 10°C beyond the range of expected flight temperatures shall be demonstrated.

Mechanical functions, which have been adequately tested at the subsystem level (and do not have the potential for interference with other subsystems or structure) need not be re-verified at the satellite level.

4.10.4.7.1.1 Torque Ratio.

The torque ratio (TR) is the torque available, T_{avail}, divided by the resistive torque, T_{res}; i.e. $TR = T_{avail} / T_{res}$. It is a measure of the degree to which the torque available to accomplish a mechanical function exceeds the torque required. TR shall be verified by testing the qualification unit both before and after exposure to qualification-level environmental testing. All TR testing shall be performed at the highest possible level of assembly, in all operating positions, and under worst-case beginning of life (BOL) environmental conditions, representing the worst-case combination of maximum and/or minimum predicted (not qualification) temperatures, gradients, voltages, and vacuum or other pertinent stress conditions. The torque ratio demonstration requirement applies to all mechanical functions, those driven by motors as well as driven by springs, at BOL only. For linear devices, the term "force" shall replace "torque" throughout this section.

The required tests are:

a. The minimum available torque of the drive system (T_{avail}) shall be verified by testing of individual motors, deployment springs, and other pertinent drive systems, in all operating positions. The measurement of available torque shall not include the mechanical advantage of harmonic drives or gear systems. Kick-off springs, which do not operate over the entire range of the mechanical function shall be excluded from this test requirement. The minimum available torque shall never be less than 70615.52 dyne-cm (one in-oz).

b. The maximum resistive torque of the driven system (T_{res}) shall be verified by testing of the fully assembled driven portion of the mechanism at all operating positions. For systems that include (velocity dependent) dampers, appropriate measures shall be employed to characterize (as nearly as possible) only the frictional resistive torque.

   The minimum required test-verified torque ratios for various types of mechanism systems prior to environmental testing are:

System Type	Required TR_{min}
Systems which are dominated by resistive torques due to inertia, such as momentum and reaction wheels.	1.5
Systems which are dominated by resistive torques due to a combination of both inertia and friction, such as large pointing platforms and heavy deployable systems.	2.25
Systems which are dominated by resistive torques due to friction, such as deployment mechanisms, solar array drives, cable wraps, and despun platforms.	3.0

After exposure to environmental testing, the reduction (if any) in test-verified torque ratio shall be no greater than 10%, after appropriate consideration has been given to the error inherent in the test methods used to measure the torque ratio.

The required torque ratios should be appropriately higher than given above if:

a. The designs involve an unusually large degree of uncertainty in the characterization of resistive torques, or

b. The torque ratio testing is not performed in the required environmental conditions or is not repeatable, or

c. The torque ratio testing is performed only at the component level.

The torque ratio shall be verified to the above-stated requirements by testing flight units both before and after exposure to environmental testing. The reduction (if any) in TR shall be no greater than 10%, after exposure to environmental testing.

4.10.4.7.1.2 Minimum Clearance

The contractor shall verify adequate dynamic clearances between the payload and launch vehicle, and between members within the payload for all significant ground test and flight conditions.

The contractor shall also verify adequacy of dynamic clearances between members within the payload during ground testing for vibration and acoustics, and during flight. Additionally, a deployment analysis shall be used to verify adequacy of clearances during payload appendage deployment.

4.10.4.7.2 Life Testing

A life test program shall be implemented for mechanical and electromechanical devices that move repetitively as part of their normal function and whose useful life must be determined in order to verify their adequacy for the mission. Alternatively, the contractor may demonstrate flight heritage on a similar mechanism with similar environment (comparable in speed, mechanism size, application, lifetime, etc.) The life test program shall be developed considering performance and lifetime requirements as well as ground and on-orbit environmental conditions. The life test mechanism shall be fabricated and assembled such that it is as nearly identical as possible to the actual flight mechanism. Prior to the start of life testing, mechanisms should be subjected to the same ground testing environments that are anticipated for the flight unit. The life test should be run using on-orbit speeds and duty cycles. Testing for any mechanism requiring life testing shall be completed by CDR.

4.10.4.8 Pressure Profile

The need for a pressure profile test shall be assessed for all hardware on the satellite per the requirements of GEVS-SE Section 2.4.6. If a test is required, the limit pressure profile is determined by the predicted pressure-time profile for the nominal trajectory of the NPP launch vehicle and demonstrated per the requirements of GEVS-SE Section 2.4.6.1.

4.10.4.9 Mass Properties - The contractor shall ensure that the satellite mass properties comply with derived mission requirements.

4.10.5 Electromagnetic Compatibility (EMC) Requirements

4.10.5.1 General Requirements - The general requirements for electromagnetic compatibility are stated below. Specific requirements are found in NPP Satellite EMI requirements, GSFC 429-01-07-07.

(a) The satellite and its elements shall not generate electromagnetic interference that could adversely affect its own elements, (including the instruments) or the safety and operation of the launch vehicle and launch site.

(b) The satellite, its subsystems, components, and instruments shall not be susceptible to emissions that could adversely affect their safety or performance. This applies whether the emissions are self-generated or derived from other sources, or whether they are intentional or unintentional. The requirements in this document include an assurance that the satellite can operate satisfactorily within the environments usually encountered during integration and ground testing. However, some subsystems or instruments may have particularly sensitive sensors and electrical devices that are inherently susceptible to the EMI that may be expected in those ground environments; in such cases, special work-around procedures must be developed to meet these unique instrument needs.

4.10.5.2 Requirements Summary

4.10.5.2.1 The Range of Requirements . The contractor shall develop an EMI-Control Plan to demonstrate how the requirements of GSFC 429-01-07-07 will be satisfied. The Plan shall reflect the constraints placed on the satellite by the launch vehicle and launch site organizations, including the launch site radiation environment.

For design qualification, the contractor shall demonstrate compliance with the general requirements of section 4.10.5.1 by conducting an EMC test program in accordance with GSFC 429-01-07-07.

4.10.5.2.2 Basis of the Tests. The contractor shall develop an EMI Test Plan based on the tests and the test procedures as described in the GEVS-SE and MIL-STD-461E. The specific limits (levels) shall be as defined in GSFC 429-01-07-07. More stringent requirements may be necessary, as for example for a subsystem or instrument with very sensitive electric field or magnetic field measurements. The sequence of the EMI/EMC tests relative to the other environmental tests is optional except that magnetics tests shall not be done until all vibration testing is complete.

4.10.6 Vacuum, Thermal, and Humidity Requirements

4.10.6.1 General Requirements - The following satellite capabilities (or capabilities of elements of the satellite) shall be demonstrated to satisfy mission requirements in the vacuum, thermal, and humidity areas:

(a) The satellite shall perform satisfactorily in the vacuum and thermal environment of space.

(b) The thermal design and the thermal control subsystem shall maintain the affected hardware within the established mission thermal limits.

(c) The hardware shall withstand, as necessary, the temperature and humidity conditions of fabrication, assembly, transportation, storage, and launch.

4.10.6.2 Summary of Requirements - Table 4.10-3 summarizes the tests and analyses that collectively serve to fulfill the general requirements of section 4.10.6.1. Tests noted in the Table 4.10-3 may require supporting analyses and vice versa. The order in which demonstrations are conducted shall be determined by the contractor and specified in the Spacecraft and Satellite Integration and Test Plan.

4.10.6.3 Thermal-Vacuum

4.10.6.3.1 General Requirements. The thermal-vacuum test shall demonstrate the ability of the satellite and its elements to perform satisfactorily in functional modes representative of the mission in vacuum at the nominal mission operating temperatures, at temperatures 10°C beyond the predicted mission extremes, and during temperature transitions. The test shall also demonstrate the ability of the satellite to perform satisfactorily after being exposed to the predicted non-operating temperature limits of the mission, including the 10°C margin. Cold and hot turn-ons shall be demonstrated where applicable. The ability to function through the voltage breakdown region, if applicable, shall be demonstrated.

Components shall be subjected to a minimum of 12 thermal-vacuum cycles, at least four of which shall be at the satellite level. The complete satellite shall be subjected to a minimum of four thermal-vacuum cycles (see Table 4.10-3 for details, including cycles for modular subsystems). For components that are not sensitive to vacuum, the component-level thermal cycling tests may be conducted in air or in gaseous nitrogen environment at atmospheric pressure. If testing of assemblies with active electronic components is conducted in air, the number of cycles shall be increased to 15, and the qualification test temperature range shall be broadened to 15°C beyond each of the predicted mission extremes.

During any thermal-vacuum cycling, the rate of temperature change shall not exceed 15°C per hour, or the maximum allowable rate of temperature change, whichever is higher. Components and subsystems shall be soaked for a minimum of four hours after temperature stabilization at each hot and cold temperature extreme of each cycle. During thermal-vacuum testing the satellite shall be soaked for a minimum of four hours and thermal soaks at each temperature extreme of each cycle must be of sufficient duration to allow time for performance tests. The contractor shall state in the Spacecraft and Satellite Integration and Test Plan the proposed testing scenario for the satellite and its components. Comprehensive Performance Tests (CPT) shall be conducted at the temperature extremes of the first and last cycle of the test, with Limited Performance Testing (LPT) during the intervening cycles.

The hardware at all levels of assembly shall be operated and its performance monitored throughout the test. Redundant hardware elements shall be exercised insofar as practicable to verify the functioning of all redundant paths. At the satellite level, turn-on capability shall be demonstrated during the low temperature extreme survival demonstration and during the high temperature extreme survival demonstration. Turn-on demonstrations require that the hardware must function, but performance within specification is not required until the hardware reaches the operating range, as appropriate. The ability to function through the voltage breakdown region, if applicable, shall be demonstrated.

Table 4.10-3 Vacuum, Thermal, and Humidity Requirements

Requirement	Satellite or Highest Practical Level of Assembly	Modular Subsystem	Component*
Thermal-Vacuum	T4	T2	T8
Thermal Balance	A & T	A	A
Temperature-Humidity (Transportation & Storage)	A	A	A
Leakage1		T3	T3

1 = Hardware that passes this test at a lower level of assembly need not be retested at a higher level unless there is reason to suspect its integrity.

T3 = Test required for sealed hardware units, only.

A = Analysis required; tests may be required to substantiate the analysis.

A & T = An analysis is required to develop a mathematical model; this shall be verified by test.

* = Components of the spacecraft bus.

T4 = 4 T-V cycles required for satellite.

T2 = 4 T-V cycles required for modular subsystems having discrete components. 8 T-V cycles required if subsystem does not have discrete components.

T8 = 8 T-V cycles (total) required for components before integration on satellite. 4 of these may be at subsystem level T-V test.

Temperature excursions during the cycling of components shall be sufficiently large, but no less than 60°C minimum to maximum for critical components, to detect latent defects in workmanship unless damage to hardware will result (e.g., batteries). Cold and hot turn-on capability shall be demonstrated as part of the thermal-vacuum testing at the component level, whenever appropriate.

Outgassing procedures that are found necessary shall be made part of the thermal-vacuum test operations if no unacceptable hazards are introduced by these procedures.

4.10.6.4 Thermal Balance

4.10.6.4.1 Verification for Design Qualification. This verification shall demonstrate the validity of the thermal design and the ability of the thermal control subsystem to maintain the satellite within the established thermal limits for the mission. The analytical thermal model shall be validated by tests. The tests may be conducted as necessary on selected components and on a (hardware) thermal model of the satellite, or on the satellite. The capability of the thermal control system shall be demonstrated in the same manner. If the flight hardware is not used in the test of the control subsystem, verification of critical thermal properties (e.g., those of the thermal control coatings) shall be performed to demonstrate similarity between the item tested and the flight hardware. Prior to the test, the power dissipation and line losses of individual components shall be measured to an accuracy of 1%, where feasible. Verification of the thermal design is considered accomplished if the differences between the predicted and measured temperatures fall within the established allowable temperature differences and if the margins defined for the satellite are demonstrated. Heat rejection margin can be demonstrated by hot case temperature results, which are lower than the maximum allowable design temperatures. The thermal testing shall include demonstration that the design provides positive heater power margins (duty cycles) and adequate thermostat control (open and close points).

Thermal balance verification requires use of analytical thermal models to:

(a) demonstrate the validity of the satellite (payload instruments and spacecraft) thermal designs,

(b) predict the satellite's mission thermal performance, and

(c) predict satellite's thermal balance test performance.

The thermal balance test predictions shall be derived from the modified flight analytical models. The modifications shall reflect the actual test conditions.

4.10.6.5 Leakage - This test shall demonstrate that leakage rates of sealed hardware units are within the prescribed mission limits. Leakage rates shall be checked once early in the test sequence, and a final check shall be conducted after the final thermal-vacuum test at the subsystem or component level. Additional leak checks may be made optionally, before and after any parts of the verification program considered to induce especially high stresses that may compromise the integrity of leak-sensitive hardware.

Checks at the subsystem level need include only those items that have not been leak tested at the component level or are not fully assembled until this higher level of integration.

4.10.7 Pre-Launch Flight Operations Test Requirements

The contractor shall perform Pre-launch Flight Testing in support of Launch and Operations per the NPP Satellite SOW. Testing shall include Command, Control and Communications Segment Compatibility Testing, Space Network Compatibility Testing and End-to-End Testing.

As part of these tests, telemetry and command demonstrations shall be conducted, incorporating all required equipment: e.g., appropriate network elements, data processing facilities, and, when available, the instrument ground support equipment. The satellite contractor shall be responsible for planning and coordinating all hardware and software interfaces to the satellite. Once the data flow paths have been verified, mission simulations shall be held to validate nominal and contingency mission operating procedures and to provide for Mission Management Center Team familiarization training.

4.11 CONTAMINATION/CLEANLINESS CONTROL PROGRAM

4.11.1 GENERAL REQUIREMENTS AND DEFINITIONS

Per the requirements of the NPP Satellite SOW, paragraph 4.3.4.4, the contractor shall assure appropriate contamination control is maintained throughout all phases of integration and test. The contamination control program shall ensure that the requirements of the instruments and specific satellite elements are fulfilled. The program shall govern activities starting with the final cleaning and protection of the spacecraft bus hardware elements and continue during the assembly of the NPP spacecraft bus, the receipt and storage of the instruments, and the integration, test, and ground operations of the NPP satellite. External surface cleanliness levels equal to or better than the cleanliness requirements established in the Satellite Requirements Specificaton shall be maintained throughout the integration, test, and pre-launch operations of the satellite, using the methods defined in the Satellite Contamination/Cleanliness Control Plan (CCP) (CDRL 18).

The environment for the storage and handling of the cleaned spacecraft bus hardware and the instruments, as well as the environment during satellite integration, test, and pre-launch activities shall be controlled and operated per FED-STD-209 Class 10,000 clean room standard. Where special test facilities or launch site facilities cannot meet this clean room standard, contamination effects shall be minimized through the use of tents and localized bagging to protect contamination sensitive surfaces.

Contaminants are defined as those materials, either at a molecular or a particulate level, whose presence may degrade mission performance. The source of these contaminants may be the spacecraft bus, the satellite, the instruments, any material or equipment (including GSE) coming in contact with the satellite, the test facilities, and/or the environments to which the satellite is exposed.

4.11.2 CONTAMINATION/CLEANLINESS CONTROL PLAN (CCP)

The contractor shall prepare and implement a Satellite CCP to govern the entire cleanliness and contamination control effort. The CCP shall:

(a) Identify the contamination sensitivity, sources (including GSE), and concerns associated with each contamination sensitive hardware item.

(b) Include mission contamination control requirements applicable to each instrument (as provided by developers). This shall include the establishment of contamination allowances and budgets (see sections 4.11.2.1 and 4.11.2.2), which serve as the control criteria throughout the effort. These requirements shall reflect the susceptibility of each instrument to molecular contamination and particulate contamination as defined in the CCP for each instrument and shall provide for meeting the mission science requirements even in the allowable contamination-degraded state.

(c) Identify and describe the methods for control and methods for verification (e.g., measurements, inspections, tests, and analyses) for all contamination requirements to be used during each phase of the hardware lifetime. For each method, the documented procedure and data recording requirements shall be included or referenced.

(d) Identify the measures to be taken to ensure that the contamination allowances and requirements established in the CCP are not exceeded. This shall include establishment of criteria for defining out-of-control conditions and identification of the planned methods for dealing with them.

(e) Identify the hardware items requiring vacuum bakeout and reference the bakeout specifications for each hardware item.

(f) Include an operations flow chart including controls to be used at each step.

(g) Identify procedures for protecting contamination-sensitive items during all operations, and procedures for cleaning, bagging, transportation, etc.

Copies of all referenced analyses, procedures, standards, and specifications, shall be available upon request. The CCP shall be submitted in accordance with the CDRL.

4.11.2.1 Contamination Allowances - As a basis for contamination control activities, the contractor shall establish contamination allowances for each contamination-sensitive spacecraft hardware item such that, even when degraded by contamination within the stated allowance, the performance degradation will not preclude the meeting of mission objectives. The contamination allowances for the spacecraft bus and satellite shall reflect the allowable contamination levels for the instruments defined in the CCP for each instrument.

The allowances shall identify (separately) the maximum deposition of particulate and molecular contamination that can be present on the contamination-sensitive surfaces of each hardware item. The allowances shall also identify the maximum allowable molecular outgassing and on-orbit venting rates for the spacecraft bus that will permit meeting the surface contamination allowances. Computer-analysis programs (such as MOLFLUX) that adequately treat return flux shall be used to establish these levels, by predicting the maximum contamination deposition and fluxes that can be experienced simultaneously and still permit the satellite to meet the mission requirements. Surface cleanliness levels (molecular and particulate) shall be stated in accordance with MIL-STD-1246. Allowable outgassing levels shall be specified in terms of grams/square-centimeter/hour. Allowable venting levels shall identify the vent location and direction as well as the effluent quantity in terms of grams/hour.

All analyses performed to assess instrument and spacecraft sensitivity and to derive contamination allowances shall be documented and be made available to NASA on request.

4.11.2.2 Contamination Budget - The contractor shall establish and document a contamination budget to identify the contaminant quantity allowed to accumulate on identified areas of the hardware during each phase of the hardware lifetime (including assembly, integration and test, shipment, launch site operations, launch, and on-orbit operation) such that the total accumulating on each area throughout all operations will not exceed the contamination allowance for that area. Beginning with the start of spacecraft bus integration and test, contamination levels shall be monitored throughout each lifetime phase prior to launch. If it is found that the contamination budget is being exceeded for any area, special cleaning of the hardware and/or budget revision shall be accomplished as necessary to ensure meeting the allowances for total contamination.

The documentation of the contamination budget shall be available for NASA review at the contractor's facility, and selected documents shall be delivered to NASA on request.

4.11.3 Vacuum Bake-Outs

The contractor shall ensure that contamination-generating elements are baked out in a thermal vacuum chamber in accordance with the allowances and requirements specified in the CCP. The CCP shall identify any other assemblies (such as electronic assemblies) to be baked-out, and contractor fabrication documentation for these assemblies shall reflect this requirement. Each hardware item shall be baked out to an outgassing rate consistent with its established contamination allowances and requirements.

Prior to each bake-out, the outgassing rate of the thermal vacuum chamber, including all test equipment to be contained in the chamber during bake-out, shall be measured with temperature controlled quartz crystal microbalances (TQCM's).

The bakeout procedure for each hardware item shall be documented in individual bake-out specifications and referenced in the CCP. -The bake-outs shall be monitored with TQCM's and a cold finger or collector plate at a representative location. Post vacuum bake-out analyses shall be performed on the cold-finger (or collector plate) sample for each chamber used and each type of hardware baked out to chemically identify the outgassed constituents collected.

4.11.4 Thermal Vacuum Test

The CCP shall include or reference the contamination controls to be exercised in preparing the thermal-vacuum chamber and the necessary fixtures and stimuli for system level tests. These shall include the operational procedures that will be followed to minimize the potential contamination hazard, from pump-down through return to ambient conditions. The CCP shall also require that flight or test hardware not be introduced into a thermal vacuum test chamber until it is determined by measurements that the chamber meets the prescribed contamination criteria. Test phases that present contamination hazards and the approaches to be taken to minimize these hazards shall be addressed.

Pre-test and post-test measurements for verifying that contamination criteria have not been exceeded shall be prescribed in the CCP. During the thermal vacuum tests the outgassing rate shall be monitored with TQCM's and recorded. Post thermal-vacuum analyses shall be performed on a sample from a cold finger or collector plate placed in the chamber to chemically identify the outgassed constituents collected.

4.12 NATURAL AND INDUCED ENVIRONMENTS

The satellite contractor shall perform analyses to establish the NPP mission environment throughout launch and operation in orbit. Information on designing for natural and induced spacecraft environments is available at: http://see.msfc.nasa.gov/see/srp.html.

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5.0 ACRONYMS

ARB	Anomaly Review Board
ASIC	Application Specific Integrated Circuits
BOL	Beginning of Life
C3S	Command, Control and Communications Segment
CAGE	Commercial and Government Entity
CAT	Category
CCP	Contamination Control Plan
CDRL	Contract Data Requirements List
CIL	Critical Items List
CPT	Comprehensive Performance Test
CVCM	Collected Volatile Condensable Mass
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic and Electromechanical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ELV	Expendable Launch Vehicle
FMEA	Failure Modes and Effects Analysis
FTA	Fault Tree Analysis
GEVS-SE	General Environmental Verification Specification for Space Transportation Systems and ELV Payloads, Subsystems and Components
GFE	Government Furnished Equipment
GIDEP	Government/Industry Data Exchange Program
GSFC	Goddard Space Flight Center
GSE	Ground Support Equipment
Hz	Hertz
LPT	Limited Performance Test
MAR	Mission Assurance Requirements
MCM	Multi-Chip Modules
MRB	Material Review Board
NPP	NPOESS Preparatory Project
PCB	Parts Control Board
PCP	Parts Control Plan
PO	Purchase Order
PPL	Preferred Parts List
PRA	Probabilistic Risk Assessment
PWB	Printed Wiring Board

RFO	Request for Offer
RSDO	Rapid Spacecraft Delivery Office
SAM	Systems Assurance Manager
SOW	Statement of Work
TQCM	Temperature Controlled Quartz Crystal Microbalances
TR	Torque Ratio